ILC Positron Production Target Simulation

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A photon-positron conversion target of the undulator or laser based polarized positron source is optimized using a modified GEANT-3 program adapted to count the spin transfer. High intensity positron beam with around 0.75 polarisation could be achieved choosing tungsten conversion target of 0.3 and 0.7 radiation lengths for the undulator and laser case respectively.

1 Positron Sources

Currently two scenarios are considered to generate polarized positrons for the ILC. Both are utilizing low energy circularly polarized photons and high energy electrons to boost these photons to MeV energies and then convert them into electron-positron pairs. Each method named after the photon source as undulator [1] or laser [2] based positron production. In

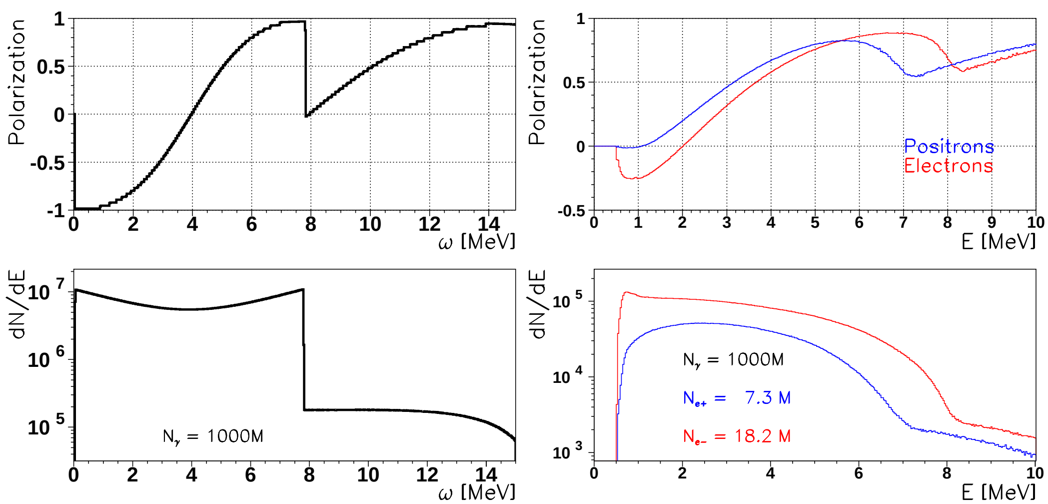

Figure 1: Polarisation distribution and spectrum of undulator photons (left) and positrons/electrons behind $0.2X_0$ tungsten (right).

this study [3] we will vary thickness and material of the production target to optimize the positron yield and polarisation.

2 Simulation Tools and Considered Polarized Processes

To achieve high number of positrons the target should be thick, of the order of one radiation length, $1X_0$ hence, the MeV photons may initiate showers, or at least 2-3 generations of particles and we would need a proper tracking tool like EGS or GEANT.

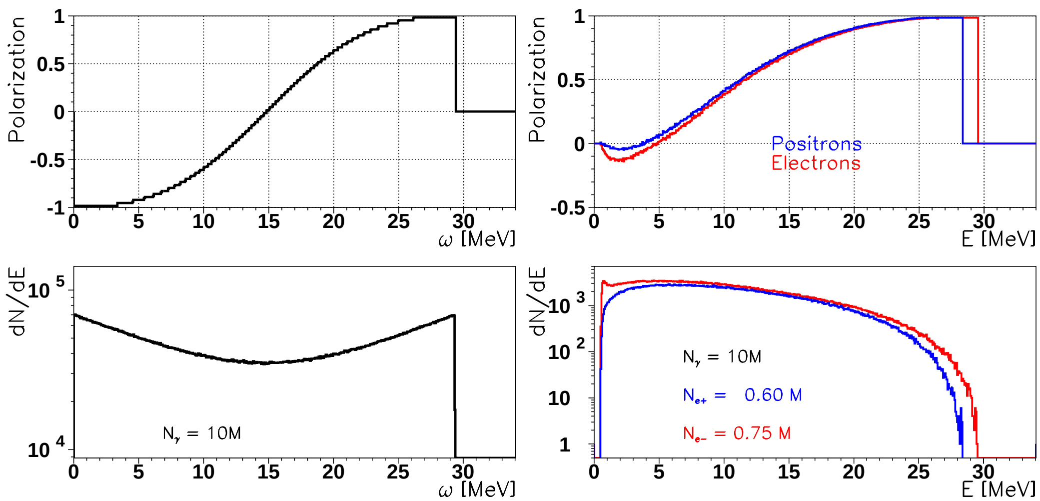

Figure 2: The same as in Figure 1 for a laser scattering Compton photons and $0.6X_0$ tungsten target

Process	Particles
Pair creation	$\vec{\gamma} \to \vec{e^+}\vec{e^-}$
Compton scattering	$\vec{\gamma} + e^- \to \vec{\gamma}\vec{e^-}$
Photoeffect	$\vec{\gamma} + e^- \to \vec{e^-}$
Annihilation	$\vec{e} + e^- \to \vec{\gamma}$
Bremsstrahlung	$\vec{e} + N \to \vec{e} + N + \vec{\gamma}$
Multiple Scattering	$\vec{e} + N \to \vec{e} + N$
Energy loss dE/dX	$\vec{e} + Ne \to \vec{e} + Ne^*$

Table 1: Modified GEANT-3 processes with polarisation transfer. Vector sign indicates polarized particle

To address the polarisation issue one have to take care also about the polarisation tracking. This has been incorporated into the EGS by K. Flöttmann [4] and into the GEANT-4 by DESY-Zeuthen E166 group [5]. Here we will use GEANT-3 [6] modified in a way to account polarisation transfer in the processes summarized in table 1. For the multiple scattering and dE/dX energy loss continuous approximations there are certain difficulties to treat the depolarisation especially for energies below the critical E_C and this is mostly because lack of the theoretical and experimental input. Anyhow, for our calculations we use straight trajectory/no depolarisation for the dE/dX loss and $(q + \cos\theta)/(1 + q\cos\theta)$ approximation as depolarisation factor for a θ multiple scattering angle with $q = (\gamma^2 - 1)/(\gamma^2 + 1)$ where γ is the Lorentz factor.

3 Results

One example of the simulation outcome for a $0.2X_0$ tungsten is shown on Figure 1 where initial photons originate from a helical 1m long undulator with k=0.19 on a 46.6 GeV energy electron beam (E166 experiment configuration). On the lower right figure one can find also total number of the positrons/electrons for the 10^9 simulated initial photons. Figure 2 displays results for the initial Compton photons produced by a 532 nm laser, scattered on 1.3 GeV electrons with a crossing angle of 8 deg. Number of simulated Compton

events is 10^7. Using positrons intensity dN/dE and polarisation P distributions we can form a product $P^2 dN/dE$ (Figure 3) to serve as a figure of merit for the target material and thickness optimization.

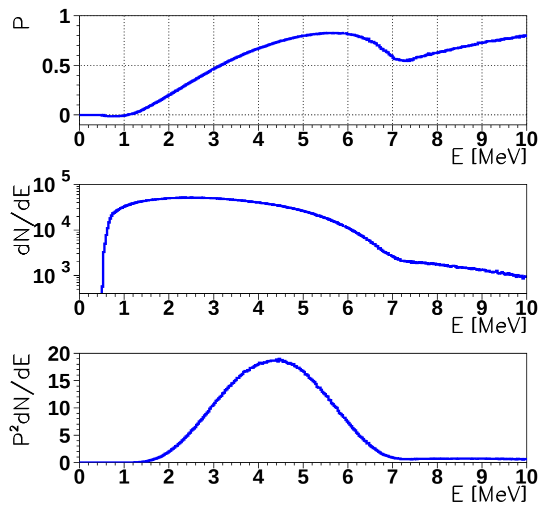

Figure 3: Figure of merit derived for the $0.2X_0$ W case. (Figure 1).

4 Optimal Target

To choose best production target we try tungsten and titanium changing their thickness by $0.04X0$ steps, each time recording the positrons yield, polarisation and energy at the maximum figure of merit. Resulting numbers are displayed on Figure 4 and Figure 5 for the undulator and laser case respectively.

One can note that in general the positron polarisation depends weekly on the target thickness i.e. the target optimization could be done by maximizing only the positron yield. The distributions also indicate that the tungsten is preferable with a thickness of $0.3X_0$ for the undulator and $0.7X_0$ for the laser case.

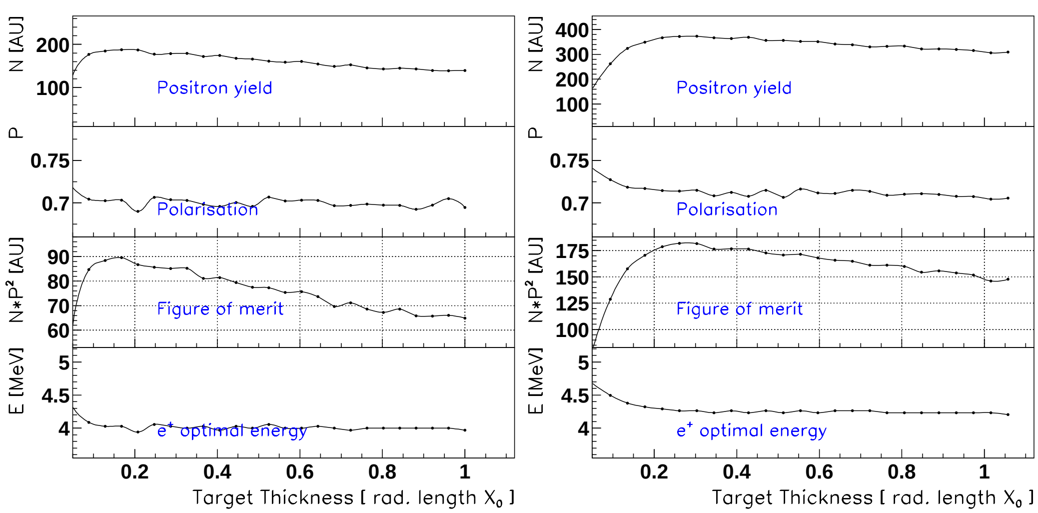

Figure 4: Undulator produced positrons intensity, polarisation, figure of merit and energy versus titanium (left) and tungsten (right) target thickness.

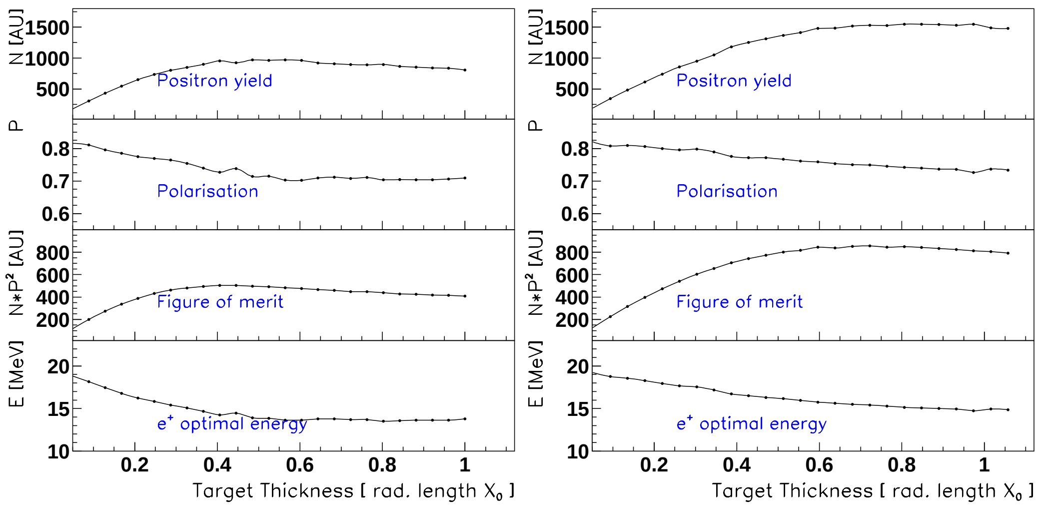

Figure 5: The same as in Figure 4 for the laser produced positrons.

5 Summary

In addition to the existing MC programs GEANT-3 is modified to count the polarisation. For energies lower than the critical, calculation errors could be large, special attention deserve multiple scattering and continuous energy loss.

For the target choice polarized calculations could almost be escaped, its sufficient to maximize the positron yield.

References

[1] G. Alexander et al., "Undulator-based production of polarized positrons: A proposal for the 50-GeV beam in the FFTB", SLAC-TN-04-018.

[2] K. Sakaue *et al.*, "Polarized positron generation based on laser Compton scheme and its polarization measurements," Int. J. Mod. Phys. B **21** (2007) 519.

[3] Slides:
`http://desy.de/~vaagn/psource/LCWS-2007-gharibyan.pdf`

[4] K. Flöttmann, "Investigations Toward the Development of Polarized and Unpolarized High Intensity Positron Sources for Linear Colliders", Ph.D. Thesis, DESY 93-161.

[5] GEANT4 physics reference manual, Chapter Polarized Electron/Positron/Gamma Incident.

[6] *GEANT - Detector Description and Simulation Tool* CERN Program Library Long Writeup W5013;